

# DRAFT LAKE MEMPHREMAGOG PHOSPHORUS TOTAL MAXIMUM DAILY LOAD

Vermont Department of Environmental Conservation

May 2017



# 1 CONTENTS

---

1	Contents.....	i
1.1	List of Tables .....	ii
1.2	List of Figures .....	ii
2	General Watershed Setting.....	1
3	Impairment of Water Quality Standards .....	2
4	Sources of Phosphorus Loading to Lake Memphremagog .....	4
5	Establishing Lake Segment Loading Capacities .....	9
5.1	Modeling Methods.....	9
5.1.1	In-Lake Model Development.....	9
5.1.2	Watershed Model Development .....	10
5.1.3	Memphremagog BMP Scenario Tool (M-BMP).....	11
5.1.4	Evaluation of Modeling Approach .....	11
5.2	Development and Application of a Spreadsheet Tool for TMDL Load Reduction Analysis .....	11
5.3	Seasonal Variation .....	14
5.4	Consideration of Climate Change .....	14
6	Establishing Allocations.....	16
6.1	Wasteload Allocation – General Approach.....	16
6.1.1	Wastewater Treatment Facilities – Wasteload Allocations .....	16
6.1.1.1	Future Growth in Wastewater Loads.....	19
6.1.2	Developed Land – Wasteload Allocations.....	19
6.1.2.1	Setting Wasteload Allocations for Developed Land.....	22
6.1.2.2	Future Growth in Developed Land.....	22
6.2	Load Allocation.....	23
6.3	Margin of Safety.....	26
6.4	TMDL Allocation Summary.....	26
7	Reasonable Assurance and Accountability .....	28
7.1	Reasonable Assurance .....	28
8	Implementation .....	31
9	Monitoring Plan .....	32
10	Public Participation .....	33
11	References .....	34

## 1.1 LIST OF TABLES

Table 1. Land use in Vermont portion of Lake Memphremagog watershed.....	1
Table 2. Vermont Phosphorus Criteria for Lake Memphremagog Segments.....	2
Table 3. Annual phosphorus loads to each lake segment in kg during the 2009-2012 base period with Quebec loading shown in (red).....	5
Table 4. Land use area and estimated loading to Lake Memphremagog for the Vermont watershed.....	5
Table 5. Source categories for Vermont phosphorus loads.....	12
Table 6. WWTF permitted flow and concentration with the resulting annual loading and average loading over the modeling timeframe (2009-2012).....	17
Table 7. Alternative approaches to setting annual wastewater treatment phosphorus load limits along with current permitted loading limits.....	19
Table 8. Cropland BMP application rates by Soil Hydrologic Group.....	24
Table 9. Current proposed set of BMPs to meet TMDL phosphorus load reduction targets across all land use sectors except WWTF.....	25
Table 10. Proposed allocations for Lake Memphremagog TMDL along with Base Load and the resulting percent reduction required. ....	26

## 1.2 LIST OF FIGURES

Figure 1. Land use in the Lake Memphremagog watershed showing town (white) and major watershed boundaries (black). ....	1
Figure 2. Average annual total phosphorus on Lake Memphremagog based on Lay Monitoring Program data. ....	3
Figure 3. Modeled phosphorus loading to Lake Memphremagog from the Vermont portions of the watershed .....	5
Figure 4. Proportion of modeled phosphorus loading to Lake Memphremagog by land use, from the four major Vermont tributaries and the Vermont direct watershed and the Quebec watershed. ....	7
Figure 5. Estimated land use phosphorus loading rate to the main lake segment in kilograms per square kilometer based on the calibrated land use phosphorus export model. This does not address estimated loading from septic systems, stream channel instability or WWTF loading.....	8
Figure 6. Defined lake segments used for in-lake modeling.....	9
Figure 7. A Schematic for the Memphremagog Spreadsheet Tool for TMDL Load Reduction Analysis....	13
Figure 8. Vermont Lake Memphremagog Base phosphorus loads 2009-2012 compared to the Vermont Lake Memphremagog TMDL loading capacity and allocations by sector in MT/yr.....	27

## 2 GENERAL WATERSHED SETTING

Lake Memphremagog is an international waterbody with over 73% of its surface area in Quebec, while 27% is in Vermont. Currently the Quebec portions of Lake Memphremagog meet applicable phosphorus guidelines for the Province. Nonetheless, through the Quebec Vermont Steering Committee on Lake Memphremagog, collaborative efforts have supported modeling and efforts to reduce loading in both Vermont and Quebec, and also an international agreement on the implementation of this Total Maximum Daily Load (TMDL) is being contemplated.

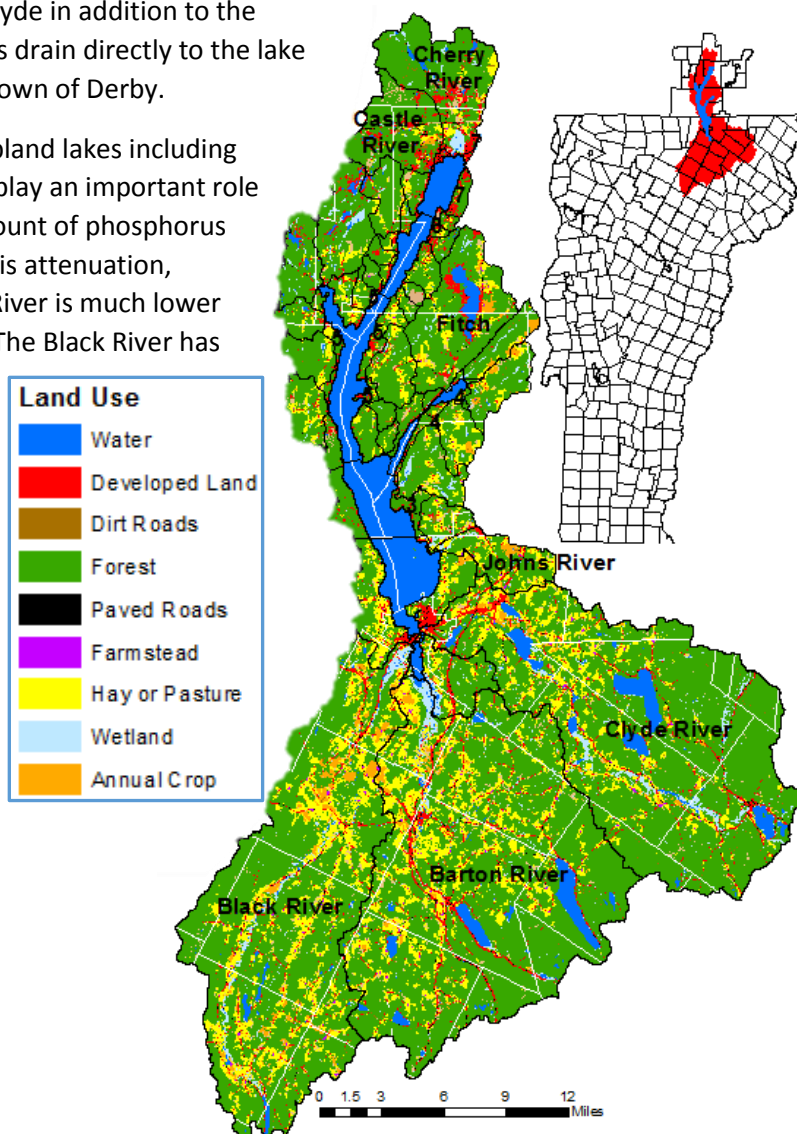
While most of the lake surface area is in Quebec, most the lake's watershed lies in Vermont (71%) (Figure1). The Vermont portion of the watershed covers most of Orleans County including the three major lake tributary rivers: Black, Barton, Clyde in addition to the smaller Johns River. Smaller shoreline areas drain directly to the lake including Newport City and Town and the Town of Derby.

The watershed includes a high density of upland lakes including many in the Clyde River watershed. These play an important role in the watershed by settling out a large amount of phosphorus from upland sources. Largely because of this attenuation, loading on a per acre basis from the Clyde River is much lower than that for the Barton and Johns Rivers. The Black River has the highest loading due to more intensive agricultural land use, and fewer areas of phosphorus attenuation.

Table 1 identifies the approximate land use breakdown within the Vermont portion of the lake watershed.

*Table 1. Land use in Vermont portion of Lake Memphremagog watershed.*

Land use	Percent of Vermont watershed
Developed	6%
Agricultural	17%
Forest/Wetland	77%



*Figure 1. Land use in the Lake Memphremagog watershed showing town (white) and major watershed boundaries (black).*

### 3 IMPAIRMENT OF WATER QUALITY STANDARDS

---

Water Quality Standards (WQS) are the foundation for a wide range of programs under the Clean Water Act (CWA). They serve multiple purposes including establishing the water quality goals for a specific waterbody, or portion thereof, and providing the regulatory basis for establishing water quality-based effluent limits beyond the technology-based levels of treatment required by CWA Sections 301(b) and 306. The water quality criteria within WQS serve as targets or endpoints for CWA restoration activities such as TMDLs.

Water quality criteria define the chemical, physical and biological conditions which are needed to support and protect designated uses of surface waters. Most water quality criteria are numeric expressions with measurable parameters. Numeric criteria specify measurable levels of particular chemicals or conditions allowable in a water body. When pollutants cannot be precisely measured, narrative criteria are used to express a parameter in a qualitative form.

Based on the Vermont Water Quality Standards (VT WQS), Lake Memphremagog segments are Class B(2) waters with designated uses that include:

- Aquatic biota
- Aquatic habitat
- Swimming and other primary contact recreation
- Boating and related recreational uses
- Fishing and related recreational uses
- Aesthetics
- Public water source
- Irrigation of crops and other agricultural uses

The pollutant of concern for this TMDL is phosphorus because it is causing or contributing to excessive algal biomass in the lake, thus impairing the swimming and aesthetic uses. Monitoring data indicate phosphorus levels are elevated above established phosphorus criteria for the Main Lake as indicated in Section 29A-302(2)(C) of the 2017 VT WQS and as noted in Table 2 below.

*Table 2. Vermont Phosphorus Criteria for Lake Memphremagog Segments*

Lake Segment / Waterbody ID	Total Phosphorus Criterion (mg/l)*
Main Lake / VT17-01L01	0.014
South Bay / VT17-01L02	0.025

\*The Vermont Water Quality Standards specify that these criteria shall be achieved as the annual mean total phosphorus concentration in the photosynthetic depth (euphotic) zone in central, open water areas of each lake segment.

As noted in Table 2, the VT WQS identify separate numeric phosphorus targets for each lake segment. Currently, in-lake data indicates that the South Bay is meeting the numeric criteria. However, prior to 2008 both lake segments were considered in exceedance of the criteria. Based on analysis undertaken in response to watershed project implementation efforts at that time, data indicated that the South Bay achieved compliance with the VT WQS, and that segment was delisted during the 2008 303(d) listing cycle.

To assess attainment of annual mean total phosphorus criteria for Lake Memphremagog, The Vermont Department of Environmental Conservation (VTDEC) uses the total phosphorus concentrations obtained through the Lay Monitoring Program. A segment is determined to be in non-attainment/impaired when the annual mean total phosphorus concentrations in the euphotic zone in the lake segment consistently exceed the applicable total phosphorus concentration criterion in Section 29A-302(2)(C) of the VT WQS (VTDEC, 2017). Figure 2 shows the annual mean concentrations for the main lake segment in Vermont – the segment is used to measure overall total phosphorus concentration compliance for the Lake in Vermont.

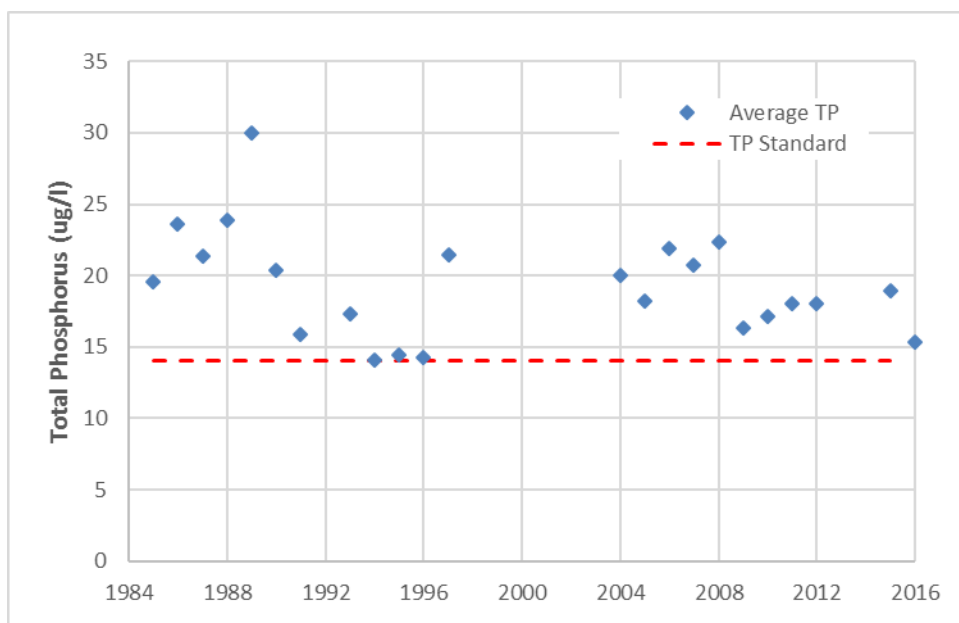


Figure 2. Average annual total phosphorus on Lake Memphremagog based on Lay Monitoring Program data.

As the main segment of the Lake in Vermont remains on the 303(d) List of Impaired Waters, the Environmental Protection Agency's (EPA) regulations for implementing CWA section 303(d) are codified in the Water Quality Planning and Management Regulations at 40 CFR Part 130. The law requires that states establish priority rankings and develop Total Maximum Daily Loads (TMDLs) for waters on the lists of impaired waters (40 CFR 130.7). Lake Memphremagog is identified as a high priority for TMDL development on the 303(d) List of Impaired Waters.

A TMDL specifies the maximum amount of a pollutant that a waterbody can receive and still meet applicable WQS. A mathematical definition of a TMDL is written as the sum of the individual wasteload

allocations (WLAs) for point sources, the load allocation (LAs) for nonpoint sources and natural background, and a margin of safety (MOS)[CWA 303(d)(1)(C)]:

$$\text{TMDL} = \Sigma \text{WLA} + \Sigma \text{LA} + \text{MOS}$$

Where:

- WLA = wasteload allocation, or the portion of the TMDL allocated to existing and/or future point sources.
- LA = load allocation, or the portion of the TMDL attributed to existing and/or future nonpoint sources and natural background.
- MOS = margin of safety, or the portion of the TMDL that accounts for any lack of knowledge concerning the relationship between effluent limitations and water quality, such as uncertainty about the relationship between pollutant loads and receiving water quality, which can be provided implicitly by applying conservative analytical assumptions or explicitly by reserving a portion of loading capacity.

The following sections of this report document the necessary steps in determining a Total Maximum Daily Load including:

- characterizing the impaired waterbody and its watershed;
- identifying and inventorying the relevant pollutant source sectors;
- applying the appropriate WQS
- calculating the loading capacity using appropriate modeling analyses to link pollutant loads to water quality; and
- identifying the required source allocations.

## 4 SOURCES OF PHOSPHORUS LOADING TO LAKE MEMPHREMAGOG

---

There are a wide variety of both nonpoint and point sources that contribute phosphorus to Lake Memphremagog. These have been estimated through a land use based phosphorus export model developed and calibrated based on direct phosphorus load estimates from tributaries by the Vermont Department of Environmental Conservation in consultation with partners in Quebec. This is described in Chapter 5 of the TMDL and in greater detail in a Lake Memphremagog TMDL modeling documentation report (VTDEC 2017.)

The total estimated loading to Lake Memphremagog from all sources from the 2009-2012 timeframe based on the model was 69 metric tons per year (mt/yr) of which 53 mt/yr were estimated to come from the Vermont portion of the watershed and 16 mt/yr from the Quebec portion of the watershed. An estimated 491 kg of the loading from the Halls Creak and Johns River watersheds come from lands in Quebec while none of Vermont's watershed areas drain directly to the Quebec portion of the lake. Wastewater treatment plant sources in Vermont and Quebec account for 1% of the total loading to the lake over the same period. The remaining 99% of the loading comes from agriculture, developed, and natural (including forest, shrub, wetland and water) lands that make up the non WWTF load in Table 3 and Figure 4.

Table 3. Annual phosphorus loads to each lake segment in kg during the 2009-2012 base period with Quebec loading shown in (red).

	Wastewater	Developed	Natural	Stream	Agriculture	Total VT	Total Quebec	Total
VT Lake	647 (0)	10791 (244)	6426 (73)	10776 (0)	24034 (173)	52674	491	53165
Quebec Lake	60	6526	3442	0	5442	0	15470	15470
Total lake	707	17561	9941	10776	29649	52674	15961	68635

The largest source of phosphorus from the Vermont watershed is from the agricultural sector, estimated at 46% of the loading to Lake Memphremagog, followed by loading from developed land at 22%, stream channel erosion at 21% and finally natural lands at 12%. Modeling for the Lake Memphremagog TMDL further breaks down loading across several land uses for each of these major land use sectors as shown in Table 4 and Figure 3. For developed lands the largest sources of loading are developed lands as well as dirt roads with loading of 8% with lesser amounts of loading from paved roads, septic and WWTF loading. For agricultural lands, loading is most significant from hay land due to the large percentage of the watershed comprised by these lands, 11% of the watershed in Vermont, resulting in an estimated loading of 19%. This is followed by cropland, agricultural production areas and pasture lands. There is a large contribution of loading from stream channel erosion as well as forest/shrub lands and wetlands and open water in the watershed.

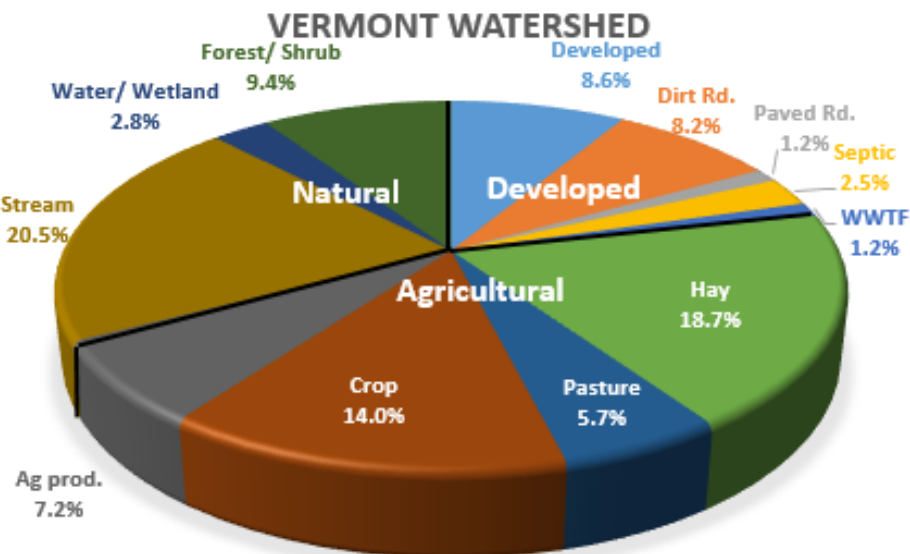


Figure 3. Modeled phosphorus loading to Lake Memphremagog from the Vermont portions of the watershed

Table 4. Land use area and estimated loading to Lake Memphremagog for the Vermont watershed.

	Area		Loading to Lake	
	km <sup>2</sup>	Percentage	kg	Percentage
<b>Developed Total</b>	<b>68.5</b>	<b>5.4%</b>	<b>11438</b>	<b>21.7%</b>
-Developed	51.7	4.1%	4427	8.4%
-Road Paved	6.5	0.5%	620	1.2%
-Dirt road	9.7	0.8%	4312	8.2%
-Barren land	0.5	0.0%	107	0.2%
-WWTF			647	1.2%
-Septic			1325	2.5%



<b>Agricultural total</b>	<b>216.6</b>	<b>17.1%</b>	<b>24034</b>	<b>45.6%</b>
-Cropland	24.4	1.9%	7398	14.0%
-Hay	144.3	11.4%	9834	18.7%
-Pasture	44.0	3.5%	3001	5.7%
-Farmstead	3.9	0.3%	3801	7.2%
<b>Natural total</b>	<b>981.6</b>	<b>77.5%</b>	<b>6426</b>	<b>12.2%</b>
-Wetland	31.1	2.5%	1072	2.0%
-Forest	854.9	67.5%	4546	8.6%
-Shrub	27.0	2.1%	391	0.7%
-Water	68.7	5.4%	417	0.8%
<b>Streambank</b>			<b>10776</b>	<b>20.5%</b>
<b>TOTAL</b>	<b>1266.6</b>		<b>52674</b>	

The phosphorus land use export model also allows estimates of loading from each land use, for each major tributary across the basin as shown in Figure 4, and for the 300+ subwatersheds used in the model. There are some significant differences in the estimated loading from different land uses and source areas between the major tributaries. The direct drainage to Lake Memphremagog and the Clyde River have the highest loading from developed land uses and WWTF at 41% and 37% respectively, with nearly 8% of loading to the Clyde coming from WWTF. The Black and Barton rivers have the highest contributions from stream channel erosion at over 25% while the Johns river has the highest proportion of loading from agriculture at 65% of the phosphorus loading from this watershed. Figure 5 gives the overall relative phosphorus loading rates to the main lakes segment across the entire Vermont portion of the watershed.

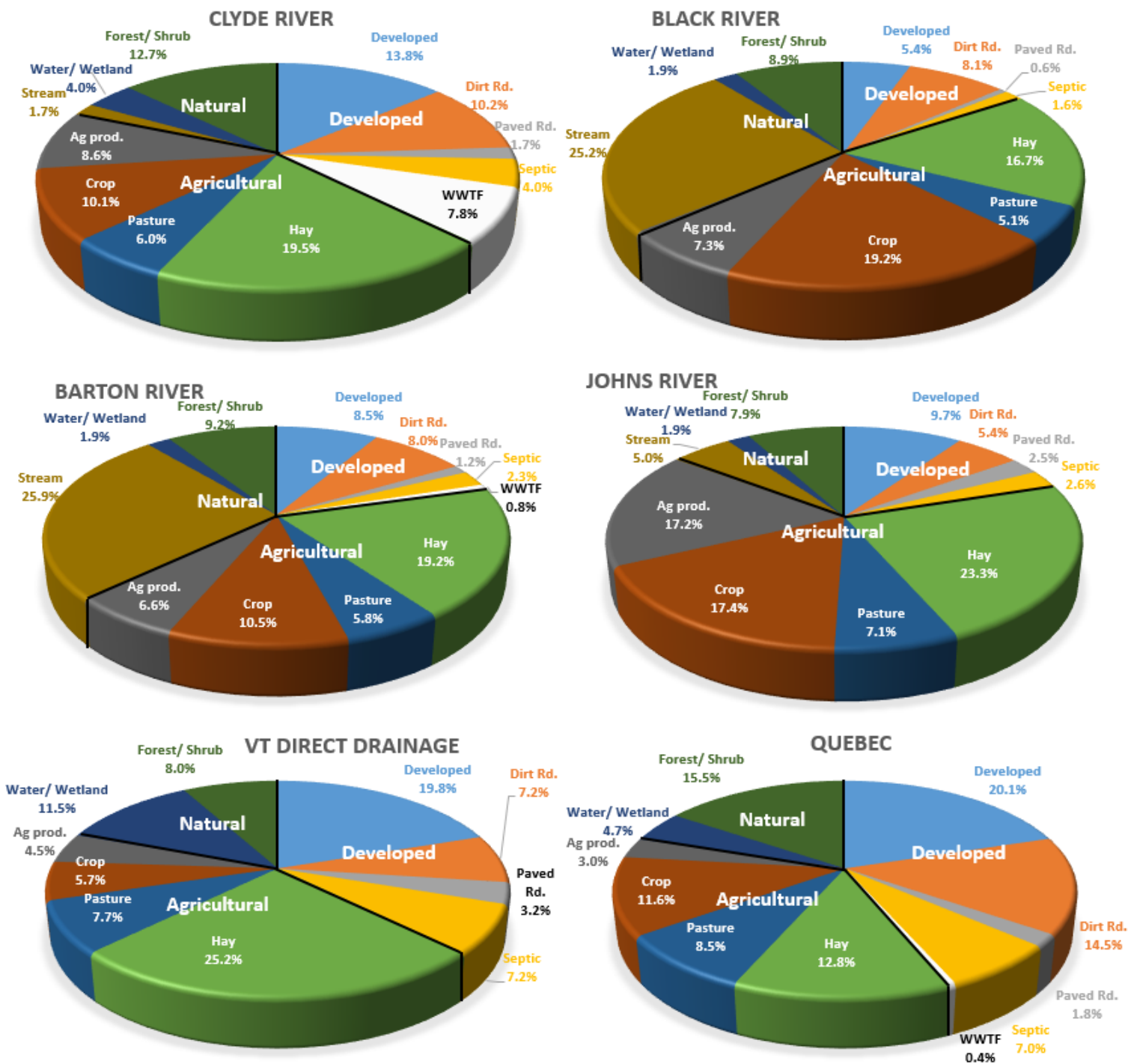


Figure 4. Proportion of modeled phosphorus loading to Lake Memphremagog by land use, from the four major Vermont tributaries and the Vermont direct watershed and the Quebec watershed.

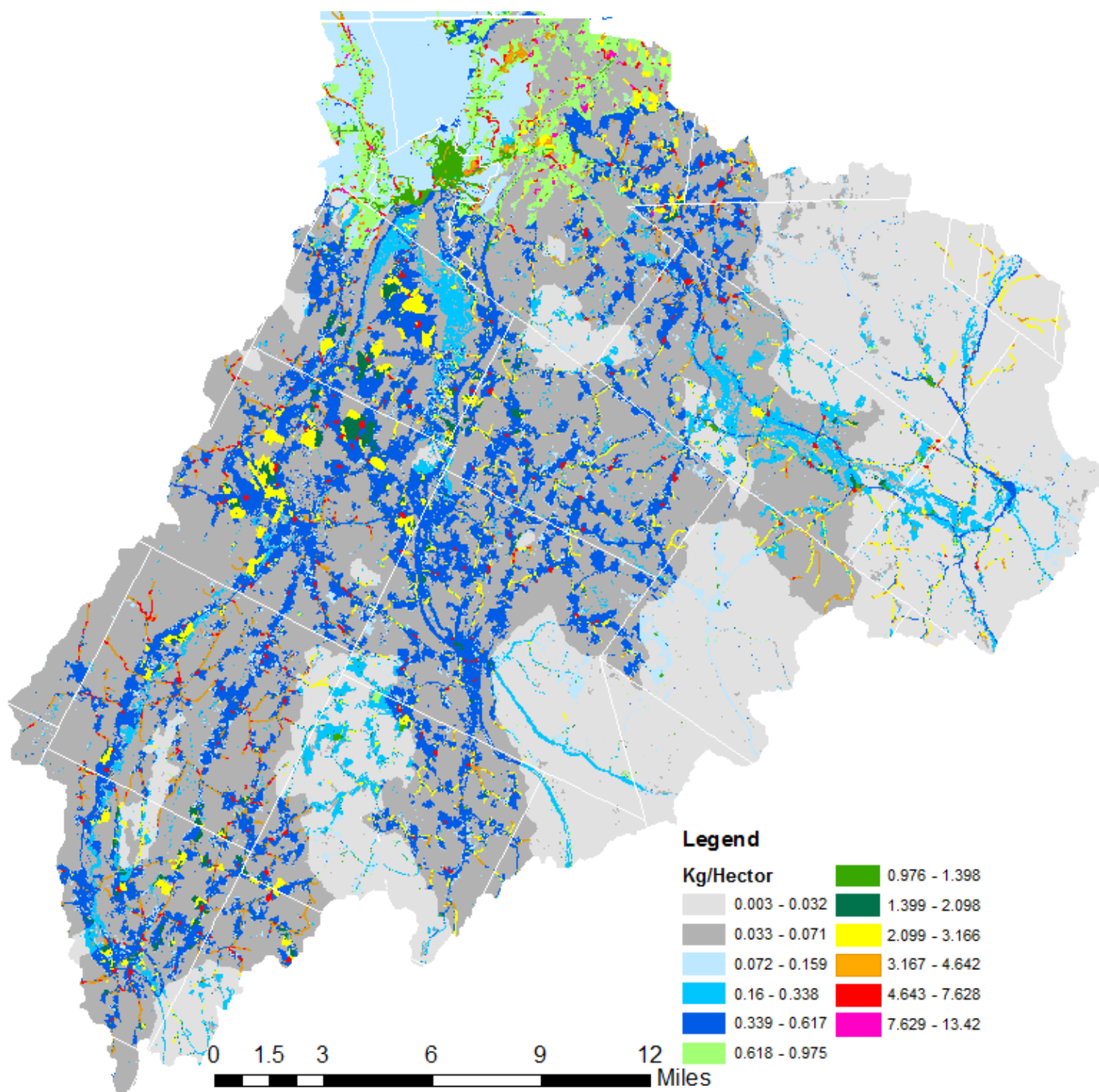


Figure 5. Estimated land use phosphorus loading rate to the main lake segment in kilograms per hectare based on the calibrated land use phosphorus export model. This does not address estimated loading from septic systems, stream channel instability or WWTF loading.

## 5 ESTABLISHING LAKE SEGMENT LOADING CAPACITIES

### 5.1 MODELING METHODS

The establishment of phosphorus loading capacities is a fundamental part of the TMDL process because they identify the amount of phosphorus that Lake Memphremagog can receive and still meet the applicable phosphorus criteria. The loading allocations from point and nonpoint sources must be set so as not to exceed the loading capacities of each segment. Loading capacities are typically derived by using water quality models that establish a relationship between the amount of the pollutant (in this case phosphorus) entering the lake and the pollutant concentrations in each segment. The relationship between loading to the South Bay and Vermont Main lake segments and main lake concentrations is more complex than this because the lake modeling accounts for a large degree of phosphorus retention in South Bay. Load reductions achieved in this watershed therefore have less impact on main lake concentrations than reductions in loading directly to the Vermont main lake segment. The modeling approach described in the following sections allows for consideration of a variety of combinations of load reduction scenarios to meet the main lake criteria.

#### 5.1.1 In-Lake Model Development

The modeling approach used for this TMDL was based on a steady-state mass balance equation for a segmented lake (Figure 6) parameterized similarly to the model used in the development of the Lake Champlain TMDL as described in the diagnostic feasibility study (VTDEC & NYDEC 1997), and adopted by the 2016 Lake Champlain TMDL. The Memphremagog adaptation of the model was developed by VTDEC in consultation with partners in Quebec, and is described in detail in the modeling documentation for the Lake Memphremagog TMDL (VTDEC 2017.)

Chloride loading to each lake segment was estimated through tributary monitoring in both Vermont and Quebec and using statistical modeling techniques described by VTDEC (2017). The modeling approach assumed that the exchange flow rates between lake segments are proportional to the cross-sectional areas of the exchange interface between lake segments, consistent with the findings from VTDEC (1997). The calibration of the exchange velocity was done by adjusting the lake wide exchange velocity using MS-Excel's solver to achieve a least-squares (minimum Root Mean Square Error (RMSE)) fit between predicted and observed chloride concentrations among the lake segments.

Phosphorus loading to the lake was estimated using the Flux 32 software (Walker 1999) using sampling data from 2005 through 2013 with phosphorus loading estimated from unmonitored portions of the watershed through a phosphorus watershed export model. This phosphorus loading estimate along with the calibrated exchange between lake segments and lake phosphorus concentration measurements from Vermont and Quebec allowed for the calibration of sedimentation velocity. Modeling suggested that a first order

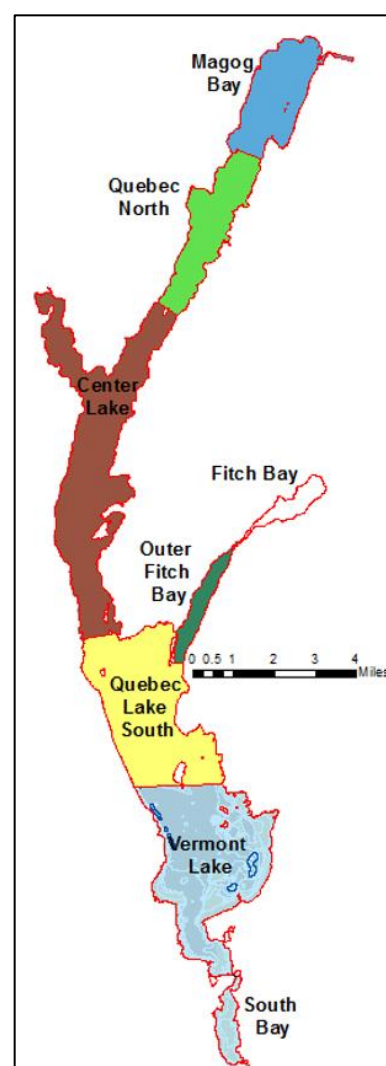


Figure 6. Defined lake segments used for in-lake modeling.

sedimentation equation would be most appropriate for Lake Memphremagog and independent settling velocities were applied to two inflow segments of South Bay and Fitch Bay while a common settling velocity was calibrated for all other lake segments to minimize RSME between modeled and measured phosphorus concentrations for all lake segments. Modeling of sedimentation rates was done for the years 2009-2012 and validation of this was applied from years 2005-2008. With sedimentation rates set for each lake segment the model was used to estimate in-lake concentrations for all lake segments, with inputs of annual flow and phosphorus load to each lake segment.

#### 5.1.2 Watershed Model Development

The land use phosphorus export model used in the Lake Memphremagog TMDL was originally developed by a private consultant, SMi Amenatech Inc., in collaboration with the Quebec Vermont Technical Committee on Lake Memphremagog and funded by the Memphremagog municipalité régionale de comté (MRC) which is a regional county municipality in Quebec (Vezina 2009). This model uses literature phosphorus export values to estimate loading for land uses and an estimate of septic system loading and then included estimated retention in lakes larger than 4 hectares to approximate phosphorus loss in the watershed. This model was developed with support from VTDEC and partners in Quebec as part of the technical committee of the Quebec Vermont Steering Committee on Lake Memphremagog. Land use and septic loading estimates were generated through several literature sources supported by the technical committee although a final calibration of the model was never completed to match modeled and measured loading through this process.

This land use export model was updated by VTDEC using a land use layer for the Lake Memphremagog basin created by combining land use provided by the Memphremagog MRC landcover layer from 2008 for Quebec and the National Agricultural Statistics Service cropland data layer produced by USDA for Vermont. The cropland data layer is a modified version of the 2011 national land cover dataset (NLCD) that has been updated to more accurately break down cropland vs hay or pasture land for agricultural lands. Roads were then burned into this layer along with farmstead areas and developed lands were broken down into impervious and pervious categories based on the 2011 NLCD impervious surface percentage layer. Loading estimates were then added from: septic systems based on proximity to surface waters; stream channel erosion based on an analysis of channel movement and net volume of sediment export and therefore phosphorus loading; and, and measurements of WWTF loading based on WWTF flows and direct effluent phosphorus sampling.

The land use export coefficients were then adjusted using excel solver to optimize the regression between measured and modeled phosphorus loading across 4 major and 24 minor tributaries, with constraints placed on the range of reasonable export coefficients. This resulted in  $R^2$  values between measured and modeled loading of 0.95 and 0.81 for the four major and 24 minor tributaries used in the calibration, respectively, indicating a high degree of model performance. Finally, explicit adjustments were made for the land use export coefficients, loading rates from stream channel erosion and septic system loading for the 4 major watersheds so loading from the model for these watersheds matched measured loading at the tributary mouths. Resulting adjustments for the four major tributaries ranged from reduction in loading for the Johns River by 14%, a reduction of loading in the Barton river by 4%, a reduction in loading of just under 1% for the Clyde river, and an increase in loading for the Black river of nearly 5%. The set up and calibration of this model is described in detail in the modeling documentation for the Lake Memphremagog TMDL report (VTDEC 2017.)

The modeling results were used for three main purposes as part of TMDL development:

1. To quantify annual phosphorus loads from existing land-use and watershed process sources – this information is needed for the establishment of load and wasteload allocations;
2. To support the estimates of phosphorus load reductions potentially achievable through implementation of a mix of BMPs – an important part of evaluating the level of “reasonable assurance” that allocations for nonpoint sources can be achieved; and
3. To estimate phosphorus loads from unmonitored drainage areas for input to the lake model.

#### 5.1.3 Memphremagog BMP Scenario Tool (M-BMP)

The Memphremagog BMP (Best Management Practice) Scenario Tool, or M-BMP is a spreadsheet-based modeling tool designed to estimate how much phosphorus reduction could potentially be achieved by various mixes of BMPs in each watershed, and is a modified version of the Lake Champlain Phosphorus Scenario Tool built for the Lake Champlain TMDL (Tetra Tech 2015c). It uses land use phosphorus model-generated baseline loading rates for each land use sector together with BMP efficiency information generated through a Lake Champlain SWAT model, or literature values, to estimate the amount of phosphorus reduction potentially achievable from a wide variety of user-selected BMP scenarios in each lake segment watershed. VTDEC made extensive use of M-BMP when evaluating whether there was sufficient reasonable assurance that load allocations could and would be met. The M-BMP also includes phosphorus loading amounts both at the source (e.g., at a field or parking lot at the upper end of a large sub-watershed) and at the mouths of the major tributaries to the Lake – referred to as the delivered loads. The delivered loads take into account attenuation or sedimentation as flow passes through upland lakes on route to Lake Memphremagog (or phosphorus storage or loss on route to the lake) estimated by the phosphorus land use export model. More details on this tool are included in the TMDL modeling report (VTDEC 2017).

#### 5.1.4 Evaluation of Modeling Approach

Several steps were taken to ensure that the modeling work in support of the TMDL was conducted in accordance with standard modeling practices, and that modeling uncertainty was within acceptable ranges for this type of application. Steps included the establishment of technical workgroups (as described in Chapter 1) to review and provide input on the modeling approach. These workgroups included an internal VTDEC workgroup made up of staff from the Monitoring Assessment and Planning Program as well as the Lakes and Ponds Program including Eric Smeltzer who has extensive background in lake modeling through efforts on the Lake Champlain TMDL. A workgroup of the Quebec Vermont technical committee met on a number of occasions to provide technical input on the modeling approach. In addition to these workgroups, a presentation of the modeling approach was made for the Memphremagog agricultural workgroup and full Quebec Vermont Steering committee on Lake Memphremagog and adjustments were made to the model to address comments.

## 5.2 DEVELOPMENT AND APPLICATION OF A SPREADSHEET TOOL FOR TMDL LOAD REDUCTION ANALYSIS

The calibrated in-lake model (VTDEC 2017) was combined into a spreadsheet format (Microsoft Excel®) with the M-BMP and the land use phosphorus export model as shown in Figure 7 to facilitate the

analysis of TMDL load reduction policy options and scenarios. The spreadsheet tool was initialized with phosphorus loading and hydrologic input data for the 2009-2012 base period, aggregated as totals for each lake segment watershed. The base period phosphorus loads were partitioned by country as some of the Vermont drainage to the main lake in Vermont is from Quebec from portions of the Johns River and Halls Creek watersheds in Quebec. The Vermont base period phosphorus loads were further partitioned into the source categories listed in Table 5 based on delivered load estimates obtained from the Lake Memphremagog TMDL Scenario Tool (VTDEC 2017).

*Table 5. Source categories for Vermont phosphorus loads.*

<b>Source categories included in the wasteload allocation (WLA)</b>	
	Wastewater discharges
	Stormwater from developed land (non-back road)
	Stormwater from back roads
	Septic systems
	Agriculture production areas
<b>Source categories included in the load allocation (LA)</b>	
	Forest land, wetland and water
	Stream channel instability/erosion
	Agricultural land

Additional calculations are included in the spreadsheet for changes in the permitted WWTF loading from WWTF base loads, future stormwater loading, and an explicit 8% MOS was then added to each Vermont segment for the model to evaluate different TMDL allocation approaches. Another tab in the spreadsheet model was created to sum these loading adjustments and load reductions estimated through the BMP scenario across the different landuse sectors into wasteload and load allocation categories for each lake segment. This allows a BMP scenario to be built with a direct connection to the lake model producing in-lake concentration estimates as well as wasteload and load allocations expressed in the TMDL.

An assumption that phosphorus loading remains constant in the Quebec portions of the watershed was made for the purposes of the TMDL. This assumption is conservative given increased regulations in Quebec establishing a 10 meter no mow rule around lakes, increased regulation and outreach around addressing poorly functioning septic systems and intensive efforts to reduce loading in the Fitch bay watershed.



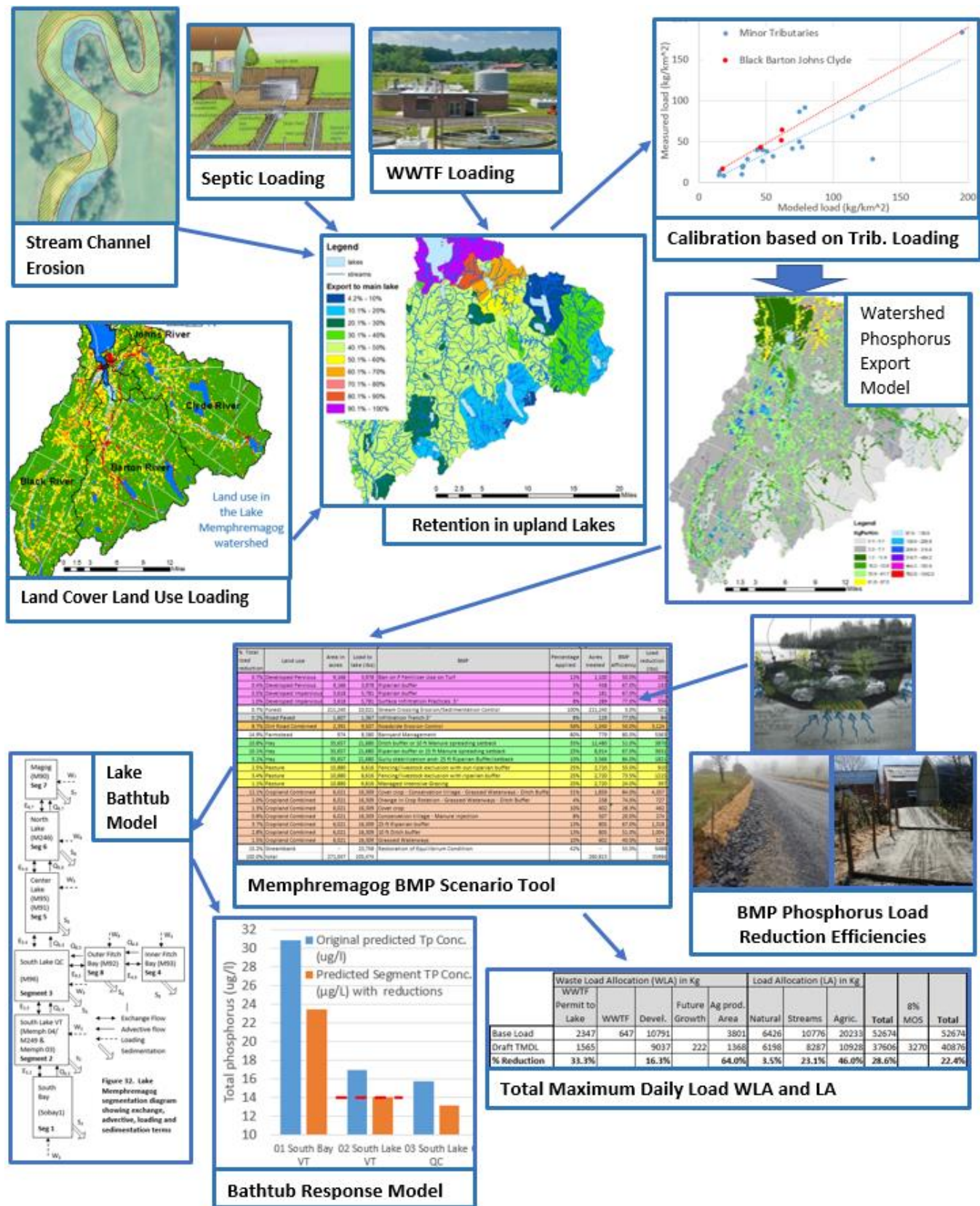


Figure 7. A Schematic for the Memphremagog Spreadsheet Tool for TMDL Load Reduction Analysis



Different BMP scenarios were then evaluated to determine the most feasible approach to meeting in-lake target concentrations. These are described in Chapter 6.

The loading capacities and wasteload and load allocations are expressed in terms of annual loads. EPA's November 15, 2006 guidance entitled "Establishing TMDL 'Daily' Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in *Friends of the Earth, Inc. v. EPA, et al.*, No.05-5015, (April 25, 2006) and Implications for NPDES Permits," recommends that TMDLs express allocations in terms of daily time increments, consistent with the D.C. Circuit's ruling. This guidance also acknowledges that the decision of the U.S. Court of Appeals for the Second Circuit, *NRDC v. Muszynski*, 268 F.3d 91 (2<sup>nd</sup> Cir. 2001), established the controlling legal precedent for cases brought in the Second Circuit, which includes Vermont. In this decision, the Court held that the Clean Water Act does not require TMDLs to be expressed in terms of daily loads, but on remand the Court required a reasoned explanation for the choice of any particular non-daily load. Vermont believes there is a reasonable basis for not including daily loads in this TMDL. In-lake concentrations of phosphorus in Lake Memphremagog are not affected by variations in daily inputs because the lake has a long residence time of 1.65 years. In evaluating the best expression of loading, Vermont determined that an annual load allocation is the most appropriate measure of how phosphorus affects Lake Memphremagog. Neither daily nor seasonal loads accurately represent the effect of phosphorus loading to the lake. In addition, Vermont's WQS express the applicable phosphorus criteria in terms of annual mean total phosphorus concentrations. The expression of the loading capacity and wasteload and load allocations on an annual basis is therefore a logical and effective approach in this case.

### 5.3 SEASONAL VARIATION

For Lake Memphremagog, critical conditions occur during the summer season when algae growth is more likely to interfere with uses. However, water quality in the Vermont main lake segment is generally not sensitive to seasonal or short term phosphorus loading. With a water residence time of about 1.65 years (VTDEC 2017), the lake generally responds to loadings that occur over longer periods of time (e.g., annual loads). Accordingly, the in-lake numeric phosphorus criteria are expressed as annual mean values (Table 2) and were selected to be protective of uses during all seasons, including the summer season. As described in Section 5.1.1, the Lake Memphremagog TMDL was developed using a steady-state modeling approach that supported the establishment of annual average phosphorus allocations designed to achieve the phosphorus criteria. Meeting the phosphorus criteria on an annual basis automatically addresses any concerns due to seasonal variation, given that the criteria were established to be protective during all seasons.

### 5.4 CONSIDERATION OF CLIMATE CHANGE

In consideration of climate change, no specific investigations were completed in the Lake Memphremagog watershed to attempt predictions in changes to phosphorus loading. However, for the Lake Champlain TMDL, a series of precipitation and temperature projections out to mid-century were considered in conjunction with the SWAT watershed modeling (Tetra Tech. 2015b). While initial modeling suggested that perhaps loading may increase by approximately 30%, after consideration of several mitigating factors, the loading was believed to be considerably less. Factors include increased in-lake loading capacity associated with higher flows and the fact that the future estimates of climate were driven by a single pessimistic projection. Additionally, aside from the potential loading effects due to

climate change, the modeled estimates did not take into account the similar types of BMPs that are likely to be implemented in the Lake Memphremagog watersheds as with Lake Champlain that will help mitigate loading. Examples of these measures include: a focus on agricultural and stormwater practices that infiltrate water and therefore minimize phosphorus runoff even during large, high intensity rainfall events; new agricultural practice requirements to stabilize soil (such as the gully stabilization requirements specified in Act 64); and stream corridor policies (such as those included in Act 110) that call for managing rivers and streams to achieve naturally stable stream conditions – conditions that will still perform well and minimize streambank erosion even with a changing climate. The iterative implementation of the Lake Memphremagog TMDL also allows for adjustments to the implementation practices in future planning cycles as changes to precipitation and temperature regimes and their impacts on nutrient loading are better understood.

So, in keeping with the premises applied in the Lake Champlain TMDL, the 8% margin of safety applied in this TMDL (5% in Lake Champlain) is believed to be sufficient for the protection of potential effects of long-term climate change.

## 6 ESTABLISHING ALLOCATIONS

---

As described earlier, a TMDL can be described as the sum of the individual wasteload allocations (WLAs) for point sources, the load allocations (LAs) for nonpoint sources and natural background, and a margin of safety (MOS). Under the regulatory definition of WLA at 40 C.F.R. § 130.2(h) and EPA's longstanding interpretation, point sources that discharge pollutants to waters of the United States and are subject to the jurisdiction of the National Pollutant Discharge Elimination System (NPDES) permit program are required to be assigned to the WLA. All other sources – both point sources and nonpoint sources – are included in the load allocation. States (and EPA) have the discretion to include point sources that are not subject to the NPDES permit program in the WLA portion of a TMDL, but they are not required to do so (Wayland and Hanlon, 2002). This chapter describes the allocations that are established and how they were developed. VTDEC developed the allocations to be consistent with the recent Lake Champlain TMDL due to similarities in phosphorus loading sources, regulations, and funding to support the implementation of the TMDL.

### 6.1 WASTELOAD ALLOCATION – GENERAL APPROACH

The phosphorus wasteload allocations in the Lake Memphremagog TMDL for Vermont point sources are divided into two groupings. The first includes the Vermont Wastewater Treatment Facilities (WWTFs) whose discharges are authorized by Vermont's NPDES permits. The second contains stormwater related phosphorus sources in the general category of developed land sources, which includes stormwater runoff from sources such as municipal and residential areas, construction sites, state highways and back roads. This developed land category incorporates stormwater sources that require state NPDES permits; stormwater sources that are subject to other, non-NPDES, state permits; and other stormwater runoff from developed land that may not be subject to either type of state permit (such as stormwater from small impervious areas below the State's permitting threshold). More information on the approach to the stormwater portion of the WLAs is included below in Section 6.1.2. Information on the WWTF portion of the WLAs is included immediately below in Section 6.1.1

#### 6.1.1 Wastewater Treatment Facilities – Wasteload Allocations

As detailed earlier, wastewater treatment facilities are not the dominant source of phosphorus to Lake Memphremagog. To minimize the financial impact of WWTF WLA reductions on communities DEC will employ flexibility in meeting WLA targets by:

- Expressing effluent phosphorus limits in permits as total annual mass loads.
- Providing a period of time for optimization to be pursued and the corresponding load reduction results to be realized, and then commencement of the process to upgrade phosphorus treatment facilities will be required when actual phosphorus loads reach 80% of the TMDL limits.
- Establishing phosphorus compliance schedules in discharge permits that allow adequate time for planning, engineering and municipal budgeting.
- Providing other forms of flexibility that support achieving the wasteload allocations in an optimally cost effective manner, including phosphorus trading and integrated planning and permitting.

Table 6 below shows the current permitted daily flow, current phosphorus concentration limit, and the resulting annual total permitted loading for the four facilities in the Lake Memphremagog watershed. The Brighton facility doesn't have a concentration limit, so 5 mg/l is assumed as a maximum concentration for this facility. This table also shows the average phosphorus load from 2009 to 2012, which indicates that all facilities are operating at less than 30% of the permitted load allowed. This is because the average concentration and flows were both substantially below the levels allowed by current permits. Another important factor to consider when setting the WLA for WWTF is that there is retention of phosphorus, which is captured in the modeling of in-lake sedimentation, both in South Bay, and in the many upland lakes along the Clyde River for the Brighton Facility. The model estimates that 46% of phosphorus from the Barton and Orleans facilities, 37% of the loading from the Brighton Facility, and 100% of the loading from the Newport facility make it to the Main Lake.

*Table 6. WWTF permitted flow and concentration with the resulting annual loading and average loading over the modeling timeframe (2009-2012)*

	<b>Permit Flow (MGD)</b>	<b>Permit Conc. (mg/l)</b>	<b>Permit Load (lbs.)</b>	<b>Average Load 2009-2012 (lbs.)</b>
<b>Barton</b>	0.265	1.0	811	247
<b>Brighton</b>	0.150	5.0*	2293	650
<b>Newport</b>	1.300	0.8	3179	862
<b>Orleans</b>	0.190	1.0	582	84
<b>Total</b>	<b>1.905</b>	---	6865	1843

\*Brighton does not have a permit concentration limit for phosphorus so 5 mg/l used to calculate annual loading

The WWTF WLA was set based on an evaluation of the loading reductions possible through regulatory requirements and through the tactical basin planning process. A 31% load reduction across non WWTF loading sectors described later in this chapter is used to identify the maximum allowable WWTF load of 3,110 lbs. (or 1410 kg) annually. The current permitted loading from WWTF to the Main Lake is 4,663 lbs. per year and needs to be reduced to 3,110 lbs., or 33%, to meet in lake phosphorus concentration targets. The Agency of Natural Resources wasteload allocation process, Administrative Rule 87-46, describes how the Agency makes wasteload allocations among competing dischargers as necessary to meet water quality standards. As described in the WLA process the guiding priorities though this process is to:

- 1) Provide maximum protection of the water resource.
- 2) Ensure equity among existing dischargers
- 3) Allow comparable capacity for future growth
- 4) Maximize the benefit/cost ratio of the allocation
- 5) Minimize the number of Wastewater treatment facilities discharging to the state's waters

The WLA process also identifies three alternatives for evaluation and allows for additional alternatives which appear to be reasonable in the judgement of the Secretary for the situation under consideration.

The first alternative described in the rule, WLA alternative A, is uniform effluent concentration limitations for all dischargers with in the segment, with total maximum daily loads based on treatment plants design flow projections. This requires permits for all facilities to be set at an annual load of 0.65 mg/l times their permitted annual flow which results in the annual loading limits shown in Table 7. This

alternative would require upgrades for the Brighton WWTF and so does not maximize the benefit cost ratio of the allocation.

The second alternative described in the rule, WLA alternative B, is a TMDL allocation for each discharger based on existing and projected populations or population equivalents. Populations were calculated based on the 2010 census for the villages of Barton at 737, the Island Pond CDP at 821, and Orleans Village at 818. The City of Newport WWTF also receives sewage from the Town of Derby however the populations served by this system is not as narrowly defined so a precise population estimate based on census is not easily applied. Accordingly, for this calculation the 2010 census populations for the City of Newport and Derby Center were combined for a population of 5186. The total population served was divided through the total WWTF load, yielding a per-capita loading of 0.5 lbs. per person, which was apportioned to each facility based on the population assumed to be served by that facility (Table 7). A more precise way of generating population estimates served by each facility is needed before this alternative is used to set the WLA. Based on the currently available population estimates this alternative would require upgrades for the Brighton WWTF, as well as likely upgrades or limitations on future growth for the Barton WWTF, and so does not maximize the benefit cost ratio of the allocation.

The third alternative described in the rule, WLA alternative C is to selectively increase the required treatment level for facilities with the greatest impact on the receiving water due to size or location, until water quality standards are attained. The Newport WWTF has the largest impact on lake concentrations due to its large allocation (3179 lbs.) and the fact that it enters the lake without any opportunities for retention. In this scenario, the WLA was reduced for the Newport facility to 1631 lbs. (equivalent to 0.41 mg/L), to meet target lake concentrations. The Newport facility has operated at an annual loading of less than 970 lbs. since 2009 which suggests that the facility may be able to continue to increase flows before reaching 80% of the WLA. However, as flows increase the phosphorus removal efficiency of the facility may be reduced and so this may require facility upgrades or place limitations on future growth. Given the uncertainty about future costs, it is challenging to evaluate the cost benefit of this approach. Further, this scenario is inequitable among dischargers, with potential costs for the City of Newport while leaving in place the full allocation for remaining towns including Brighton at the equivalent effluent concentration of 5.0 mg/l.

The final alternative, WLA alternative D, is not specifically identified in the WLA process but is reasonable in the judgement of the Secretary for the situation under consideration. This alternative is to reduce the loading across all facilities by the same percentage from the facilities current permitted loading, on an annual basis. This alternative would require a 33% reduction in the annual loading allowed for each facility as shown in Table 7. This alternative would not require any upgrades in the first permit cycle and allows for at least an additional 50% future growth above the maximum annual loading since 2009 for each of the facility before reaching 80% of the proposed annual loading limits. This alternative follows the guiding principles of equity, allowing for future growth, and maximizing the benefits vs the costs, and so is presented in the DRAFT TMDL as the preferred alternative.

Table 7. Alternative approaches to setting annual wastewater treatment phosphorus load limits along with current permitted loading limits.

	Current permit	WLA-A. Uniform effluent concentration of 0.65 mg/l*	WLA-B. Population (0.5 lbs per person)*	WLA-C. Reduction of Newport WLA to 1631 lbs *	WLA-D. 33% load reduction for all facilities*
<b>BARTON (mg/l / lbs.)</b>	1.0 / 811	0.65 / 527	0.46 / 339	1.0 / 811	0.67 / 542
<b>BRIGHTON (mg/l / lbs.)</b>	5.0** / 2293	0.65 / 298	0.90 / 411	5.0 / 2293	3.34 / 1532
<b>NEWPORT (mg/l / lbs.)</b>	0.8 / 3179	0.65 / 2584	0.65 / 2593	0.41 / 1631	0.53 / 2125
<b>ORLEANS (mg/l / lbs.)</b>	1.0 / 582	0.65 / 377	0.71 / 409	1.0 / 582	0.67 / 388
<b>Total load (lbs.)</b>	<b>6865</b>	<b>3786</b>	<b>3782</b>	<b>5317</b>	<b>4587</b>
<b>Total loading to Main Lake (lbs.)</b>	<b>4663</b>	<b>3110</b>	<b>3102</b>	<b>3115</b>	<b>3116</b>
<b>Percent of TMDL load (89,993 lbs.)</b>	6.0%	4.0%	3.9%	4.3%	4.0%
<b>Reduction from current permit load</b>	0%	45%	45%	23%	33%
<b>Non WWTF load reduction required</b>	33.9%	31.2%	31.2%	31.2%	31.2%
<b>Potential required upgrades in first permit cycle</b>		Brighton	Barton, Brighton	Newport	None

\*Concentrations for WLA alternatives were derived by dividing the proposed annual load by the current design flow. These are provided for context, and are not necessarily reflective of final permitted monthly average concentration limits.

\*\*Brighton does not have a permit concentration limit for phosphorus so 5 mg/l was used to calculate annual loading.

#### 6.1.1.1 Future Growth in Wastewater Loads

EPA's definitions of wasteload and load allocations refer to both future, as well as existing, point and nonpoint sources (40 C.F.R. 130.2(g) and (h)). The Vermont Wasteload Allocation Process requires that future population growth be considered in establishing wasteload allocations. Capacity for future growth in wastewater flows is built into the design and permitting of wastewater treatment facilities, and future growth capacity is therefore included in the individual facility wasteload allocations proposed in Table 7.

The allowance made within the TMDLs' wasteload allocations for future increases in wastewater flows and phosphorus loads can be assessed by comparing the average recent discharge levels which are at most 62% of the permitted flows for facilities in the Lake Memphremagog watershed. Wasteload allocation alternative D shown by Table 7 provides a cost-effective approach to reducing WWTF loads in a manner that preserves future growth opportunities for all facilities, while achieving a 33% effective reduction in total WWTF load to the lake.

#### 6.1.2 Developed Land – Wasteload Allocations

EPA interprets 40 C.F.R. § 130.2(h) to mean that allocations for point source discharges subject to the NPDES permit program must be included in the wasteload allocation portion of the TMDL (Wayland and Hanlon, 2002). In addition to wastewater treatment facility discharge permits, the NPDES program includes the following other permit types in Vermont which are applicable in the Lake Memphremagog watershed.

- Permits issued for stormwater discharges from certain parcels based on Residual Designation Authority (RDA, presently presumed to apply to all parcels with three or more acres under-treated impervious surface)
- Certain individual or general stormwater permits for new development or redevelopment.
- General construction site stormwater permits (CGP), and individual construction stormwater permits (INDC).
- General multi-sector industrial stormwater permits (MSGP)
- Concentrated Animal Feeding Operation (CAFO) permits

The State of Vermont also administers the following permit programs pursuant to State authorities.

- Transportation Separate Storm Sewer System permits (TS4)
- Municipal roads general permit
- Large Farm Operation Permits (as applied to production areas only)
- Medium Farm Operation Permits (as applied to production areas only)
- Certified Small Farm Operation Permits (as applied to production areas only)

Unlike continuous discharges from WWTFs, stormwater runoff is driven by brief and intermittent rainstorms or snowmelt events, and is highly variable in quantity and phosphorus content from one event to the next. Monitoring phosphorus loads in stormwater runoff is technically difficult and expensive because of the variable nature of these events, making it difficult to assign and enforce facility-specific effluent limits. Phosphorus loads from construction sites are especially challenging to monitor or estimate. Because of these monitoring difficulties and the geographic scale of the Lake Memphremagog TMDL, it was not technically feasible to separate the allocations for stormwater sources requiring NPDES permits from the allocations for other stormwater nonpoint and non-NPDES regulated point source categories based on land use. EPA guidance states that NPDES-regulated stormwater discharges may either be expressed as individual wasteload allocations (for each source, for example) or as a single categorical allocation for all NPDES-regulated stormwater discharges when data are insufficient to assign each source an individual wasteload allocation. (Wayland and Hanlon, 2002; Sawyers and Best-Wong, 2014). The 2002 guidance also explains that stormwater discharges from stormwater point sources not currently subject to NPDES regulations may also be included in the wasteload allocation portion of a TMDL.

The NPDES stormwater-related phosphorus sources listed above, except for CAFOs which are addressed by separate WLAs as discussed below, are included in the general aggregate WLA category of developed land sources. This category also includes runoff from non-NPDES regulated point source and nonpoint sources such as residential areas, small construction sites, and back roads, since it is not technically feasible to distinguish loads among the various sources and accurately separate the allocations into WLAs and LAs. In addition, some stormwater discharges from developed land may in the future become subject to NPDES permits (through the exercise of residual designation, for example), and including the loads within the WLA now is reasonable and consistent with EPA's guidance discussed above.

Phosphorus loading from developed land was estimated using the land use based phosphorus export model, as described in Chapter 5. The WLA portion of these TMDLs includes a category for developed land sources, while recognizing that this category incorporates both point sources that require NPDES permits, and point and nonpoint sources that do not require such permits.

The developed land WLA set overall allocations and reduction targets for all developed land for the Vermont portions of the Lake Memphremagog watershed. To comply with the WLAs, the permitting authority (VTDEC) will need to demonstrate that the combined effect of the mix of permits issued will achieve enough phosphorus reduction to meet the allocation. Some permit categories are better suited than others at achieving phosphorus reductions through retrofit requirements. One benefit of establishing overall WLAs for developed land is that it provides a certain amount of flexibility to the permitting authority – VTDEC can consider the totality of the stormwater permitting programs as it designs the most effective program to achieve the overall load reduction. While the WLA was calculated based on a defined set of best management practices that could be modeled at the watershed scale, alternative practices resulting in equal phosphorus loading may be used as final permits are developed or as more cost effective alternatives are identified through the tactical basin planning process.

Discharges of manure, litter, and process wastewater from CAFOs are subject to NPDES permits and state LFO, MFO, or CSFO permits, and therefore, require wasteload allocations. Vermont issued a general permit for medium CAFOs in 2013 but to date, there are no CAFOs currently covered by the permit. Large and small CAFOs would receive individual permits and the State has not permitted any at this time. Any NPDES permits issued by VTDEC for CAFOs would prohibit discharges of manure, litter, and process wastewater except when precipitation causes an overflow during greater than 25 year/24-hour storm events. In anticipation of the possibility that a few CAFOs may be permitted in the future, the TMDL includes allocations for all agricultural production areas in the Lake Memphremagog watershed (based on data available in 2013, as described in VTDEC 2017) on the wasteload allocation side of the TMDL equation. This is like the approach described above for developed land stormwater WLAs, in that the agricultural production areas WLAs cover discharges from both NPDES-regulated and non-NPDES regulated agricultural production areas. The allocations were determined by applying an 80% reduction to the modeled base loads for production areas (referred to as “farmsteads” in the modeling and scenario tool reports) for 80% of the farmstead area to account for the fact that some farmsteads have already adopted many best management practices prior to modeling timeframe, resulting in a 64% load reduction from production areas. The 80% reduction level was used to approximate the reduction estimated to be feasible with state-of-the-art barnyard management BMPs that will be required as part of the State’s commitment to inspections and required BMP implementation in addition to CAFO inspections. The remaining 36% of the base load was used as the wasteload allocation. Note that any phosphorus runoff from fields, including runoff from land application of manure, litter, and process wastewater by CAFOs consistent with nutrient management plans developed in accordance with CAFO requirements, will remain part of the load allocation as an agricultural stormwater discharge (see 40 CFR § 122.23(e)), which is excluded from the definition of “point source” (see 40 CFR § 122.2).



#### ***6.1.2.1 Setting Wasteload Allocations for Developed Land***

The approach to setting the developed land WLA for the Lake Memphremagog TMDL through the scenario tool was similar to the approach used for the Lake Champlain segments where a moderate load reduction was necessary. This included several BMP's across developed lands including:

1. Applying a ban on P fertilizer use on turf to 12% of the developed pervious lands in the watershed (based on estimates of how much land area this would impact from the Lake Champlain Scenario tool report (Tetra Tech, 2015c).
2. Applying riparian buffers to 5% of developed pervious and impervious lands across the watershed through Lake Wise BMP programs and the Trees for streams program.
3. Surface infiltration practices for 8% of the watershed with a treatment depth of 0.5 inches based on a permit that will require stormwater treatment for all parcels with over 3 acres of impervious surfaces and technical and financial support through stormwater master planning and Clean Water Initiative funding to support unregulated landowners and municipalities in treating runoff from impervious surfaces.
4. Infiltration trench for 10% of paved roads area with a treatment depth of 0.5 inches achieved through both the Municipal Roads General Permit and the TS4 permit for state transportation infrastructure.
5. Applying road side erosion control practices for 65% of dirt roads focused on those which have a high erosion potential based on an erosion potential analysis due to the Municipal General Roads Permit which requires treatment of dirt roads which are hydrologically connected to surface waters over a 20-year timeframe.

#### ***6.1.2.2 Future Growth in Developed Land***

The increased phosphorus loading due to stormwater growth from developed lands over the next 20 years was calculated based on the methodology developed for this purpose for the Lake Champlain TMDL described in Appendix A of the Lake Champlain TMDL (US EPA 2016). This methodology was based on several assumptions regarding the amount of newly permitted impervious surface growth for each lake segment between 2005 through 2014. This data has not been made available for the Lake Memphremagog basin and so an average of the growth per existing developed acreage across the entire Lake Champlain basin in Vermont of 0.35% per year was applied to this TMDL. The range for annual growth rates for lake segments ranged from a low of 0.02% for South Lake A, up to 0.83% for St Albans Bay. Some basins that seem to have the most similar development patterns as Lake Memphremagog are Missisquoi Bay and Otter Creek which had annual growth rates of 0.25% and 0.26% respectively so the average of 0.35% can be considered a conservative assumption.

An assumption was made that for each area of permitted impervious growth an equal amount of unpermitted development has been occurring. The estimated increase in loading was then calculated by multiplying the estimated new permitted area by the estimated loading for this area of developed lands, based on the assumption that new unpermitted growth requires no stormwater treatment. The estimate of loading for permitted sites is based on the standard treatment scenario with a phosphorus removal efficiency of 71.2% resulting in a multiplier of 0.288 as stated in Appendix A of the Lake Champlain TMDL (US EPA 2016). Finally, an area equal to 11% of annual percentage growth is estimated

to be redeveloped and a credit of 25% load reduction was taken based on the retrofit treatment efficiency standard. The total loading from stormwater growth is estimated at 236 kg based on this analysis.

The reduction in loading from forest lands that have been converted to developed impervious lands also needs to be included in this calculation. This was done by estimating the percentage of forested lands which would be developed and removing that percentage of the forested loading from the model, resulting in a net loading from development over twenty years of 143 and 79 kg for segments 1 and 2, respectively, for a total loading for future growth of 222 kg over 20 years.

## 6.2 LOAD ALLOCATION

The TMDL load allocations apply to nonpoint sources in the categories of agriculture, forest land, and stream channel instability, as well as to any non-NPDES regulated point sources to the extent they exist (VTDEC is not specifically aware of such sources). The approach to setting the load allocation was the same across the entire Vermont portion of the Lake Memphremagog watershed and was similar in many ways to the approach that was followed for the Lake Champlain TMDL.

Only a modest reduction of 5% from the forest sector was applied due to limited phosphorus reduction opportunities for this sector. These load reductions will be achieved through updates to the Acceptable Management Practices (AMP's) that include practices to improve erosion control for forest roads and water crossings to avoid water quality impacts as well as outreach to loggers and forest lands owners about these practices and through the support of a skidder bridge rental program.

Loading reductions achievable thorough the restoration of stream equilibrium condition were estimated based on the BMP treatment efficiency that was developed for the Lake Champlain TMDL using phosphorus loading derived from SWAT modeling in relation to the dominant channel evolution stage at the HUC12 level. The Lake Champlain TMDL applied the restoration of stream equilibrium condition to streams above the 25<sup>th</sup> or 50<sup>th</sup> phosphorus loading percentiles for all lake segments except for Missisquoi where this BMP was applied to all streams. Since a SWAT model was not used in the development of the Lake Memphremagog TMDL an identical calculation could not be made for this watershed.

As an alternative approach, an estimate of loading from unstable stream channels was made for reaches where phase 2 stream geomorphic assessments were completed. Based on this assessment, the restoration of stream equilibrium conditions BMP was applied to the 42% of the loading that was estimated to come from reaches that had lost access to their floodplain. In addition to this, several reaches on the Black River and a few on the Barton River had elevated levels of estimated streambank erosion and loading based on high rates of planform adjustment likely driven by a loss of riparian vegetation and not stream incision. For these streams, increasing riparian vegetation will increase boundary conditions and will reduce erosion and loading rates from stream channels in the Lake Memphremagog basin.

The restoration of equilibrium conditions for unstable streams in the Lake Memphremagog watershed will be achieved through improved floodplain and river corridor protection, river corridor easements, and the regulation of stream alterations. This will also be supported though the restoration of buffers

along streams which will be supported through new Required Agricultural Practices (RAPs), as well as voluntary buffer planting programs for both agricultural and developed lands in the basin.

The approach to setting load reductions achievable from agricultural lands was to approximate the BMP's that would be installed based on new Required Agricultural Practices (RAPs) adopted in the fall of 2016 as well as technical and financial assistance provided through a RCPP (Regional Conservation Partnership Program) grant and other funding sources which are being targeted based on water quality sampling results. Specific BMP's that were applied included:

1. Ditch and Riparian buffers or manure spreading setbacks on 40% and 30% of hay lands respectively along with grassed waterways to stabilize gully erosion on 3% of hay land.
2. Applying fencing on pasture lands with and without buffers (25% each) and managed intensive grazing for 25% of pasture lands. The later BMP was based on load reduction estimates developed for the Chesapeake Bay watershed.
3. A matrix of BMP's for croplands shown in Table 8 below based on soil hydrologic group.

*Table 8. Cropland BMP application rates by Soil Hydrologic Group.*

<b>Cropland BMP</b>	<b>A -Excessively drained</b>	<b>B -Well Drained</b>	<b>C-Poorly drained</b>	<b>D-Very poorly drained</b>
<b>Cover crop - Conservation tillage - Grassed Waterways - Ditch Buffer</b>	20%	30%	40%	25%
<b>Change in Crop Rotation - Grassed Waterways - Ditch Buffer</b>	0%	0%	0%	25%
<b>Cover crop</b>	15%	15%	10%	10%
<b>Conservation tillage - Manure injection</b>	5%	5%	10%	0%
<b>Riparian buffer</b>	20%	15%	10%	10%
<b>Ditch buffer</b>	20%	15%	10%	10%
<b>Grassed Waterway</b>	10%	10%	10%	10%

The BMP's applied across all land uses is shown in Table 9 below. This table was originally developed to aid in discussions with farmers about priority BMP's so units were changed to acres and pounds so these could be more relatable. In this table, there has been an averaging across soil hydrologic groups for croplands as well as for different erosion classes for roads. The BMP applications identified represent one of many possible scenarios by which this TMDL may be achieved.

Table 9. Current proposed set of BMPs to meet TMDL phosphorus load reduction targets across all land use sectors except WWTF.

% Total load reduction	Land use	Area in acres	Load to lake (lbs)	BMP	Percentage applied	Acres treated	BMP efficiency	Load reduction (lbs)
0.7%	Developed Pervious	9,166	3,978	Ban on P Fertilizer Use on Turf	12%	1,100	50.0%	239
0.4%	Developed Pervious	9,166	3,978	Riparian buffer	5%	458	67.0%	133
0.5%	Developed Impervious	3,618	5,781	Riparian buffer	5%	181	67.0%	194
1.0%	Developed Impervious	3,618	5,781	Surface Infiltration Practices .5"	8%	289	77.0%	356
0.7%	Forest	211,240	10,021	Stream Crossing Erosion/Sedimentation Control	100%	211,240	5.0%	501
0.3%	Road Paved	1,607	1,367	Infiltration Trench.5"	10%	161	77.0%	105
9.8%	Dirt Road Combined	2,391	9,507	Roadside Erosion Control	65%	1,560	50.0%	3,574
14.7%	Farmstead	974	8,380	Barnyard Management	80%	779	80.0%	5363
12.1%	Hay	35,657	21,680	Ditch buffer or 10 ft Manure spreading setback	40%	14,263	51.0%	4423
11.9%	Hay	35,657	21,680	Riparian buffer or 25 ft Manure spreading setback	30%	10,697	67.0%	4358
1.5%	Hay	35,657	21,680	Gully stabilization and- 25 ft Riparian Buffer/setback	3%	1,070	84.0%	546
2.5%	Pasture	10,880	6,616	Fencing/livestock exclusion with out riparian buffer	25%	2,720	55.0%	910
3.3%	Pasture	10,880	6,616	Fencing/livestock exclusion with riparian buffer	25%	2,720	73.5%	1215
1.1%	Pasture	10,880	6,616	Managed Intensive Grazing	25%	2,720	24.0%	397
11.9%	Cropland Combined	6,021	16,309	Cover crop - Conservation tillage - Grassed Waterways - Ditch Buffer	31%	1,859	84.0%	4,357
2.0%	Cropland Combined	6,021	16,309	Change in Crop Rotation - Grassed Waterways - Ditch Buffer	4%	238	74.0%	727
1.5%	Cropland Combined	6,021	16,309	Cover crop	12%	735	27.3%	543
0.6%	Cropland Combined	6,021	16,309	Conservation tillage - Manure injection	6%	374	20.0%	219
3.6%	Cropland Combined	6,021	16,309	25 ft Riparian buffer	13%	805	67.0%	1,318
2.7%	Cropland Combined	6,021	16,309	10 ft Ditch buffer	13%	805	51.0%	1,004
1.4%	Cropland Combined	6,021	16,309	Grassed Waterways	10%	602	40.0%	527
15.0%	Streambank	-	23,758	Restoration of Equilibrium Condition	42%	-	55.0%	5488
100.0%	total	271,047	105,474			262,355		36496

### 6.3 MARGIN OF SAFETY

The statute and regulations require that a TMDL include a margin of safety (“MOS”) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality

(CWA §303(d)(1)(C); 40 C.F.R. §130.7(c)(1)). EPA’s 1991 TMDL Guidance (USEPA, 1991) explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS must be described. If the MOS is explicit, the loading set aside for the MOS must be identified.

Although there are conservative assumptions built into the modeling approach, one of the lessons learned from the review of the 2002 Lake Champlain TMDL was that in a system as complex as Lake Champlain or Lake Memphremagog, it is difficult to assure conservatism in every modeling decision. Considering this complexity, an allocation for an explicit margin of safety equal to eight percent of the total loading capacity was set for the Vermont portions of Lake Memphremagog, based on two factors.

First, the uncertainty analysis completed as part of the lake modeling indicated that the prediction error of the model for 2005-2012 was negative 2.8 percent. A positive prediction error value means that the model predicts higher phosphorus concentrations than monitored values, indicating that there is conservatism built into the model. Negative prediction error values indicate that the model predict lower phosphorus concentrations than the actual monitored concentrations for this period, indicating that the model is under estimating (on average) the extent to which phosphorus loads elevate in-lake concentrations. A 3% MOS was added to the margin of safety to address this negative prediction error. An additional 5% was added to the margin of safety based on modeling uncertainties described in detail in the TMDL modeling report (VTDEC 2017) as well as uncertainties related to potential increases in flows and loading with climate change. VTDEC concludes that the total 8% margin that address model prediction error and general modeling uncertainties is adequate for this TMDL.

### 6.4 TMDL ALLOCATION SUMMARY

The resulting allocations by sector are shown in Table 10 along with the base loading by sector and the resulting percent reductions needed to achieve these various allocations. The WWTF allocations are listed as WLA Alternative D in Table 7, in Section 6.1.1.

*Table 10. Proposed allocations for Lake Memphremagog TMDL along with Base Load and the resulting percent reduction required.*

	Waste Load Allocation (WLA) in Kg					Load Allocation (LA) in Kg			Total	8% MOS	Total
	WWTF Permit to Lake	Average WWTF Load	Devel.	Future Growth	Ag prod. Area	Natural	Streams	Agric.			
Base Load	2458	647	10791		3801	6426	10776	20233	52674		52674
Draft TMDL	1641		8823	222	1368	6198	8287	10914	37454	3257	40711
% Reduction	33.2%		18.2%		64.0%	3.5%	23.1%	46.1%	28.9%		23%

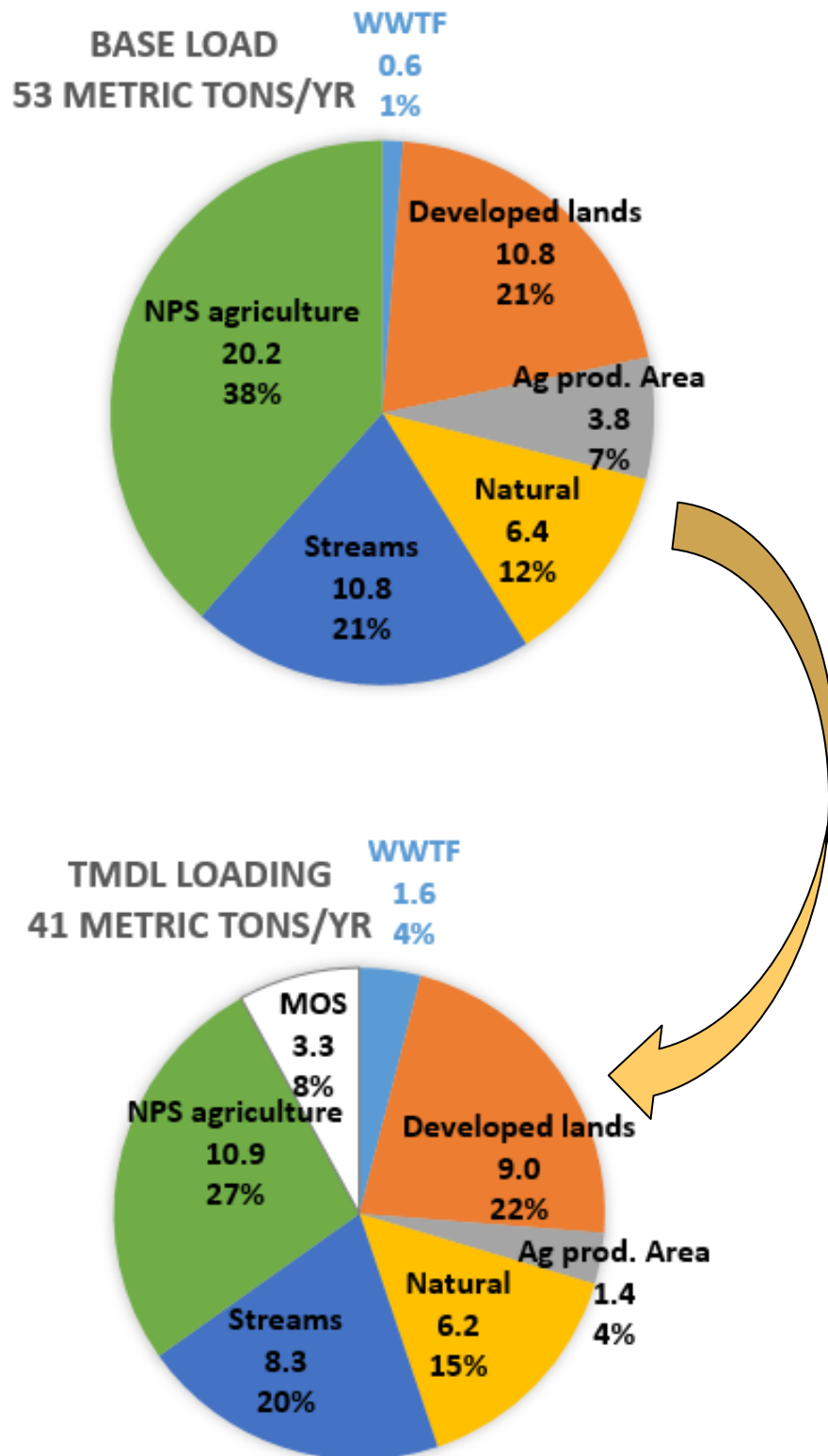


Figure 8. Vermont Lake Memphremagog Base phosphorus loads 2009-2012 compared to the Vermont Lake Memphremagog TMDL loading capacity and allocations by sector in MT/yr. Base load for Wastewater is shown as current actual loads (647 kg). Current permit limits are higher (2456 kg) and the final load allocation shows future permit limits (1641 kg) which is a reduction of 33%.

## 7 REASONABLE ASSURANCE AND ACCOUNTABILITY

---

### 7.1 REASONABLE ASSURANCE

Section 303(d) of the CWA requires that a TMDL be “established at a level necessary to implement the applicable water quality standard.” EPA regulations define a TMDL to include WLAs and LAs, and provide that “[i]f best management practices or other nonpoint source pollution controls make more stringent load allocations practicable, then wasteload allocations can be made less stringent.” 40 C.F.R. §130.2(i). EPA’s TMDL guidance further explains that when a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA assumes that nonpoint source load reductions will occur, the TMDL must provide “reasonable assurances” that nonpoint source control measures will achieve expected load reductions for the TMDL to be approvable (USEPA, 1991; see also Perciasepe, 1997). This information is necessary to determine that the TMDL, including the load and wasteload allocations, has been established at a level necessary to implement water quality standards.

Where a TMDL is developed for waters impaired by both point and nonpoint sources (and non-NPDES regulated point sources), EPA’s determination of reasonable assurance that the TMDL’s LAs will be achieved considers whether practices capable of achieving the specified pollutant load: (1) are technically feasible at a level required to meet allocations; and (2) have a high likelihood of implementation. Where there is a demonstration that nonpoint source (and non-NPDES regulated point source) load reductions can and will be achieved, a TMDL writer can determine that reasonable assurance exists and may also, if sufficient load reductions are reasonably assured, allocate greater loadings to NPDES-regulated point sources as WLAs than would otherwise be required.

Phosphorus loading in the Lake Memphremagog watershed is dominated by nonpoint sources. Without a demonstration of reasonable assurance that relied-upon nonpoint source reductions will occur, the Lake Memphremagog TMDL would have to assign commensurate reductions to the point sources. After analyzing all available information, VTDEC determined that there is reasonable assurance that the nonpoint source (and non-NPDES regulated point source) reductions can and will be achieved and that such reductions are sufficient to allocate greater loadings to the WWTFs than would otherwise be required. For the Lake Memphremagog TMDL, numerous elements combine to provide robust assurance that the necessary load reductions will occur and will achieve sufficient phosphorus reductions to meet the specified load allocations.

First, Act 64, signed into law by Governor Shumlin on June 16, 2015 includes several regulatory changes that will achieve significant phosphorus reductions. Many of these regulatory, policy and funding changes are highlighted in the Phase 1 implementation plan for the Lake Champlain Phosphorus TMDL and while this document was drafted specifically for the Lake Champlain TMDL many the regulatory approaches, technical policy and funding aspects of the phase 1 plan applies equally to the Lake Memphremagog TMDL.

Key among these new measures included in act 64 are the following, which will be applied across the entire watershed:

- Issuance of general permits to control runoff from State highways and other VTrans properties, and municipal paved and unpaved roads;

- Issuance of a general permit to address stormwater from existing developed lands equal or greater than 3 acres;
- Revision of the Vermont Stormwater Management Manual;
- Adoption of a “stormwater practices handbook” for managing runoff from non-jurisdictional projects;
- Revision of the “Required Agricultural Practices” (formerly the “Accepted Agricultural Practices”) including such programs as Nutrient Management Planning, Livestock Exclusion and certification of manure applicators;
- Creation of a Small Farm Operation certification program;
- Revision of the Acceptable Management Practices for forestry;
- Implementation of recently adopted rules controlling stream alterations and development in floodplains;
- Issuance of a new CSO Rule, replacing the 1990 CSO Control Policy;
- Development of a comprehensive TMDL implementation tracking and reporting system;
- Revision of the Agency of Natural Resources (ANR)/Agency of Agriculture, Food and Markets (AAFM) Memorandum of Understanding for the agricultural nonpoint source program;
- Establishing a long-term revenue source to support water quality improvement via the Clean Water Fund.

Of equal importance are the financial resources needed to implement the new and revised programs identified in the Basin 17 Tactical Basin Plan and covered in Act 64. In the 2015 legislative session, Act 64 established Vermont’s contribution of approximately \$5.3 million annually to the Clean Water Fund, to be raised from a surcharge on the value of property subject to property transfer tax for three years. This augmented approximately \$5M in annually-allocated State capital funds administered under the Ecosystem Restoration Grants program, with oversight by the Clean Water Fund Board, providing for a total State investment in excess of \$10M, not accounting for the surface water revolving loan fund.

As of this writing, the Vermont General Assembly, as part of the 2017 legislative session, is in the process of approving a substantial increase to water quality improvement funding, for use across all sectors as consistent with Act 64, and following through the recommendations of the State Treasurer’s [2017 Report on Water Quality Funding](#). This action responds to Governor Phil Scott’s support of the Treasurer’s recommendations, expressed as an increase in clean-water capital funding to \$20M per year in his SFY2018 budget proposal. As part of the process, the General Assembly is also contemplating repeal of the sunset on the 2015 Property Transfer Tax, ensuring continued additional State support of up to \$5.3M in non-capital water quality investments.

The criteria for prioritizing allocation of funds, which are to be implemented by the Clean Water Fund Board with legislative input, are well aligned with the new programs required by Act 64. Prior investments in staffing at Agencies of Agriculture, Food and Markets, Transportation, and Natural



Resources are being maintained to implement the Lake Memphremagog TMDL, and track progress over time.

Significant new federal funding has also been secured to support TMDL-related actions in Vermont. The USDA has committed \$674,000 million in federal funds to improve Lake Memphremagog's water quality as part of USDA's Regional Conservation Partnership Program in agreement with the Orleans County Natural Conservation District. This is in addition to \$674,000 committed by partners as significant contribution in support of this project for reducing phosphorus and sediment runoff from agricultural lands in the Lake Memphremagog and Tomifobia watershed.

Modeling and the Lake Memphremagog scenario tool have also enabled the quantification of phosphorus reductions achievable from the measures contained in Act 64, and allowed for verification that these reductions are sufficient to meet load allocations for each segment. This is described in Chapter 6 of this TMDL. Finally, through the tactical basin planning process and tracking, VTDEC will provide accountability for meeting TMDL load reduction targets. The Lake Memphremagog, Tomifobia and Coaticook Basin plan will be issued every 5 years to allow for an iterative approach for implementing the Lake Memphremagog TMDL.

To support the iterative tactical basin planning process and accountability for the TMDL, VTDEC is developing a tracking system to identify the location and phosphorus reduction capabilities of BMPs for projects supported by VTDEC and Clean Water Fund dollars or implemented as part of compliance with regulatory programs and Act 64. The Agency of Agriculture has developed a database in partnership with USDA and other organizations to track the implementation of agricultural BMPs which can be integrated into the tracking at a summary level. Similarly, VTDEC through the MRGP will be tracking road improvements and associated phosphorus reductions achieved through this permitting program. Credit for phosphorus load reductions as far back 2012 may be given for projects that were installed after modeling was completed, and that can be documented as still performing as designed. The tracking of implementation projects with associated loading reductions will allow for an evaluation of progress in meeting TMDL load reductions. This information will also be used to identify land use sectors where load reductions have exceeded expectations or others that may be lagging in which case this information will support the identification of barriers in meeting phosphorus reduction targets and the development of targeted strategies to overcome these in the next iteration of the tactical basin plan.

## 8 IMPLEMENTATION

---

The Implementation of the Lake Memphremagog TMDL will be done through the development of a tactical basin plan that will be updated every 5 years to allow for an iterative process to identify, and then implement targeted phosphorus reduction actions. While much of the necessary load reductions needed to meet the TMDL will be driven by changes in regulations, there is an opportunity through monitoring and assessment programs done in collaboration with watershed partners to use this information to target technical and financial resources to locations where the largest phosphorus load reductions are possible. The VTDEC has supported a volunteer tributary sampling program in coordination with the Memphremagog Watershed Association and Beck Pond LLC, which has sampled at over 150 sites across the Lake Memphremagog watershed over the last 11 years. The water quality sampling program began with sampling the major tributaries and has evolved to narrowly bracket phosphorus source areas. BMPs have been installed to address identified phosphorus sources which have resulted in reductions in monitored phosphorus concentrations in some cases. Other identified source areas are being targeted for stormwater, road erosion and agricultural implementation projects.

In addition to the water quality sampling program, several assessment programs including stream geomorphic assessments, road erosion inventories and capital budgets, bridge and culvert assessments, Illicit discharge detection and elimination, and Lake Wise assessments have been completed in the basin or are planned as part of the Lake Memphremagog tactical basin plan. The draft tactical basin plan for the Lake Memphremagog watershed proposes using these assessments to move forward with projects in the following areas:

- 1) Stormwater master planning has been completed for most heavily developed areas of the Lake Memphremagog Watershed and has included several potential stormwater treatment projects which have load reduction potential of over 250 lbs in total). One project in the town of Brighton is being installed in late 2016 and two of the projects have been developed to the 30% level in the towns of Derby and City of Newport and are a priority for implementation.
- 2) The Stormwater master plan for the Lake Memphremagog has also identified two potential projects with a low cost for phosphorus loading reductions by treating stormwater from VTRANS infrastructure which will support VTrans in meeting load reductions with the TS4 permit at a reasonable cost. One of these sites, an eroding gully, was identified through water quality sampling as a priority phosphorus source area.
- 3) The Northeast Kingdom Road and Rivers Workgroup has been established with members from the Orleans County NRCD, VTrans and NVDA with a focus on working with towns to help them meet requirements of the new municipal road general permit. This group is working to develop road erosion inventory and capital budget templates that will help towns most effectively reduce erosion and phosphorus loading from municipal roads.
- 4) Support for Lake Wise restoration plans for private landowners on lakes in the watershed. These restoration plans will support the restoration of riparian buffers necessary to reduce phosphorous loading and restore lakeshore habitat but will also identify small stormwater and erosion control practices that can reduce phosphorus loading to lakes at low cost where state cost share can support implementation.

- 5) Support for Trees for streams program along with other programs that restore buffers along agricultural and developed lands across the basin. Over 50 miles of unbuffered streambank have been identified based on stream geomorphic assessments of which over 9 miles have been planted over the last 5 years.
- 6) An integrated approach to working with farmers to reduce phosphorus loading through the collaboration RCPP and integrated water quality sampling program.

The draft 2017 tactical basin plan should be considered the Implementation Plan for this TMDL, and future iterations of the Lake Memphremagog tactical basin plans will include additional targeted implementation actions, using an adaptive management approach.

## 9 MONITORING PLAN

---

The Vermont Lay Monitoring program (LMP) samples phosphorus on Lake Memphremagog weekly during summer months and will be used to evaluate if in-lake concentrations meet phosphorus criteria. Lay monitors sample for total phosphorus, chlorophyll-a concentration, and water clarity every week to ten days from Memorial Day to Labor Day, collecting a minimum of eight samples. The LMP program samples using a hose to collect a depth integrated sample over the photic depth (2 times the secchi depth) in the south end of the Vermont Lake segment.

The Department also plans to maintain an ongoing tributary monitoring program targeting monthly sampling for the four major tributaries with an additional 8-12 high flow event samples per year. Effluent sampling and flow measurements will monitor wastewater treatment plan phosphorus loads to verify compliance with phosphorus wasteload allocations for each facility.

A collaborative water sampling program supported by VTDEC through the LaRosa volunteer monitoring program and Clean Water Initiative funding is also integral to the Lake Memphremagog TMDL as it will continue to locate phosphorus sources areas and evaluate load reductions achieved through the implementation of BMPs. This water sampling program is being integrated into the RCPP program to target agricultural BMP's where they can have the greatest impact. Sampling will be done in collaboration with farmers and resource staff to aid in the development of nutrient management plans and land treatment plans that truly address the primary phosphorus sources on the farm. The sampling will then continue as BMP's are installed to evaluate load reductions or if loading calculations are not possible at least changes in phosphorus concentrations before and after BMP implementation. A local BMP scenario tool will continue to be used to compare predicted vs measured load reductions achieved at a smaller scale and the scenario tool will be refined if monitoring results show significant differences in load reductions in a number of locations.

The final element of monitoring is the development of a BMP tracking tool to track BMP's implemented and to track associated phosphorus reductions as described in Section 7.

## 10 PUBLIC PARTICIPATION

---

The Lake Memphremagog TMDL was developed with several opportunities for public input. Public input was initiated in the Spring of 2016 with a meeting on Act 64 which includes many of the regulatory changes necessary to meet the TMDL which was hosted by NVDA and where an introduction to the Lake Memphremagog TMDL was provided. A more in depth public presentation was held on the evening of June 30<sup>th</sup> where an overview of the modeling approach taken to develop the Lake Memphremagog TMDL was discussed as well as the approach to developing TMDL allocations using the Lake Memphremagog Scenario tool. On August 11<sup>th</sup>, an outreach secession targeting farmers in coordination with the Orleans Natural Resources Conservation District and UVM extension was held with nearly 30 attendees of which more than half were farmers in or near the watershed. At this meeting, a proposed set of BMP's on agricultural lands was presented and feedback was received on how to improve upon this. Another meeting was held in Westmore on August 31<sup>st</sup> focused on phosphorus reduction efforts for upland lake watersheds, along with other issues to be addressed in the tactical basin plan. Finally, a public meeting was held on November 15<sup>th</sup> where a proposed WLA and LA were presented for public input and a TMDL summary was posted to the VTDEC website to disseminate information to the public.

Upon release of the draft TMDL, a public comment period will be opened for the receipt of comments on the TMDL itself. A comment response summary will then be developed whereby any changes to the TMDL can be made. The resulting TMDL and comment summary will then be submitted to EPA for approval.

## 11 REFERENCES

---

- Perciaspe, R. 1997. *New policies for establishing and implementing Total Maximum Daily Loads (TMDLs)*. U.S. Environmental Protection Agency. Washington, DC.  
[https://www.epa.gov/sites/production/files/2015-10/documents/2003\\_10\\_21\\_tmdl\\_ratepace1997guid\\_0.pdf](https://www.epa.gov/sites/production/files/2015-10/documents/2003_10_21_tmdl_ratepace1997guid_0.pdf)
- Sawyer, A and B. Best-Wong. 2014. *Revisions to the November 22, 2002 Memorandum “Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs*. U.S. Environmental Protection Agency. Washington, DC.  
[https://www3.epa.gov/npdes/pubs/EPA\\_SW\\_TMDL\\_Memo.pdf](https://www3.epa.gov/npdes/pubs/EPA_SW_TMDL_Memo.pdf)
- Tetra Tech. 2015b. *Lake Champlain Basin SWAT Model Configuration, Calibration and Validation*. Prepared for: U.S. EPA Region 1 – New England Boston MA.  
<https://www.epa.gov/sites/production/files/2015-09/documents/swat-model-configuration-calibration-validation.pdf>
- Tetra Tech. 2015c. *Lake Champlain BMP Scenario tool requirements and design*. Prepared for: U.S. EPA Region 1 – New England. Boston MA. <http://www.epa.gov/tmdl/lake-champlain-bmp-scenario-tool-report>
- U.S. Environmental Protection Agency. 1991. *Guidance for water quality-based decisions: The TMDL Process*. EPA 440/4-91-001. Washington, DC.
- US Environmental Protection Agency. 2016. *Phosphorus TMDLs for Vermont Segments of Lake Champlain*. Region 1 New England. Boston MA. <https://www.epa.gov/sites/production/files/2016-06/documents/phosphorus-tmdls-vermont-segments-lake-champlain-jun-17-2016.pdf>
- VTDEC. 2017. *Modeling Documentation for the Lake Memphremagog TMDL*. Montpelier, VT.  
<http://dec.vermont.gov/sites/dec/files/wsm/mapp/docs/Memph%20TMDL%20documentation%204-26-17.pdf>
- VTDEC & NYDEC. 1997. *A phosphorus budget, model, and load reduction strategy for Lake Champlain - Lake Champlain Diagnostic-feasibility study*. Waterbury, VT and Albany, NY.  
[http://dec.vermont.gov/sites/dec/files/wsm/lakes/docs/lp\\_lcdfs-finalreport.pdf](http://dec.vermont.gov/sites/dec/files/wsm/lakes/docs/lp_lcdfs-finalreport.pdf)
- Vezina K and Desilets, J 2009. *Rapport Final Modelisation du transport du phosphore sur L’ensemble du bassin Versant du lac Memphremagog*. Produced by SMi Amenatech inc. for MRC de Memphremagog.
- Walker W. 1999. *Simplified procedures for Eutrophication assessment and prediction: user manual*. Us Army Corps of Engineers - Waterways Experiment Station. Vicksburg, MS.
- Wayland, R and J. Hanlon, 2002. *Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs*. U.S. Environmental Protection Agency. Washington, DC. <https://www.epa.gov/sites/production/files/2015-07/documents/final-wwtmdl.pdf>